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A MORPHOMETRIC AND MERISTIC STUDY OF THE LANDLOCKED SALMON IN TAIWAN, IN COMPARISON WITH OTHER MEMBERS OF THE GENUS *ONCORHYNCHUS* (SALMONIDAE)

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Rong-Quen Jan, Ling-Chuang Jaung, Yao-Sung Lin and Kun-Hsiung Chang (1990) A morphometric and meristic study of the landlocked salmon in Taiwan, in comparison with other members of the genus *Oncorhynchus* (Salmonidae). *Bull. Inst. Zool., Academia Sinica* 29 (3, Supplement): 41-59. During October 1986 – December 1987, 52 specimens of the Formosan landlocked salmon were collected along the Chichiawan Stream, an upper stream of Tachia River, for studying morphometric and meristic characters. When the findings were compared with published data of this fish, it was found that except the more variable dorsal and pectoral rays, meristic values were relatively consistent through various studies. The findings also showed that this landlocked slamon is more closely related to the widely distributed *Oncorhynchus masou masou* than to other members in the genus *Oncorhynchus*. However, the question whether this landlocked salmon is a subspecies under *Oncorhynchus masou, (Oncorhynchus masou formosanus)*, or is merely a population of *Oncorhynchus masou masou*, remains to be answered.

Key words: Landlocked salmon, *Oncorhynchus masou formosanus*, Tachia River, Chichiawan Stream, Wu-lin Farm

The Formosan landlocked salmon, which occurred uniquely in the upper streams of Tachia River, has attracted attention in the spectrum of biogeography, geography and zoology since it was first reported in 1916 (Aoki, 1917; Behnke et al., 1962; Jordan and Oshima, 1919; Oshima, 1936; Watanabe and Lin, 1985). Moreover, this salmon is also of great interest to scientists for its occurrence in the subtropical area rather than the colder area where members of the trout (Family Salmonidae) were normally found (Kano, 1940).

In the 30's the Formosan salmon were widely distributed in six upper streams of the Tachia River (Kano, 1940). This salmon is a glacial relic and hence has been considered as a "natural monument." For this reason it had once been protected (Kano, 1940). However, this landlocked salmon had received little substantial protection before the dramatic decline of its population size in the early 80's (Lin and Chang, 1989). In 1984, in consideration of the status of this rare fish, it was classified as an endangered species by the Cultural Assets Preservation Act and its protection was again launched. In the recent years, the distribution of this salmon seems to be limited to the Chichiawan Stream, one of the six tributaries of Tachia River where the fish used to occur. The population size, as surveyed in 1987, was below 2,000 (Lin et al., 1987).

The scientific name and systematic position of the Formosan salmon has been a subject of controversy. Based on the characteristics of two specimens, Jordan and Oshima named the fish as *Salmo formosanus* in 1919. With additional information from a third specimen Oshima revised the systematic position of this fish and changed the species name as *Oncorhynchus formosanus* (Oshima, 1934). In 1935, Oshima visited the upper streams of Tachia River and collected some fresh specimens. Because these specimens showed characteristics similar to those found on *Oncorhynchus masou* (Brevoort), which was widely distributed in northern Japan, the same species name was then adopted to the Formosan salmon (Oshima, 1936). Furthermore, Behnke et al. (1962) suggested, after a review of the original description and a comparison of five specimens collected in 1960 with a topotype of *S. formosanus*, that one or more than one species of salmonids might inhabit the Tachia River systems. Recently, the systematic position of the Formosan salmon has been reevaluated by Watanabe and Lin (1985). They suggest that there is only one endemic subspecies of salmonid fish in Taiwan, and designate the fish as *Oncorhynchus masou formosanus*.

In the present study, we share the same view with Watanabe and Lin (1985) that only one endemic subspecies of salmonid fish currently occurs in Taiwan. However, we are particularly interested in whether the meristic values of the fish currently found are identical to those found in the past. This is crucial because, on the one hand, with the recent change of the distribution of this salmon, the present population may only illustrate a subset of the former one, with some specific characteristics; on the other hand, if, in the future, the distribution and the population of this salmon be reestablished by fish release, characteristics of the fish from the novel population should possibly be more similar to those from the current Chichiawan stock than to them from the former stock.

In the present study both of the original and the published data of Formosan salmon were used. Meristic values are compared pair-wisely to test a null hypothesis that specimens collected both in the present study and from various published sources belong to groups of equal means.

Furthermore, a comparison between the fish in the present study and other eight *Oncorhynchus* species from the

Pacific, as reviewed by Hikita (1962), was also made. The results may thus provide further information on the systematic position of this salmonid.

MATERIALS AND METHODS

During October 1986 – December 1987, 52 specimens of Formosan salmon were collected along Chichiawan Stream (Fig. 1). Among them 42 were collected from the wild stock (indicated elsewhere as PW) and 10 were artificially propagated (as PA). Most of the wild-stock specimens were collected on the river bank, where, for unknown reasons, dead fish occasion-

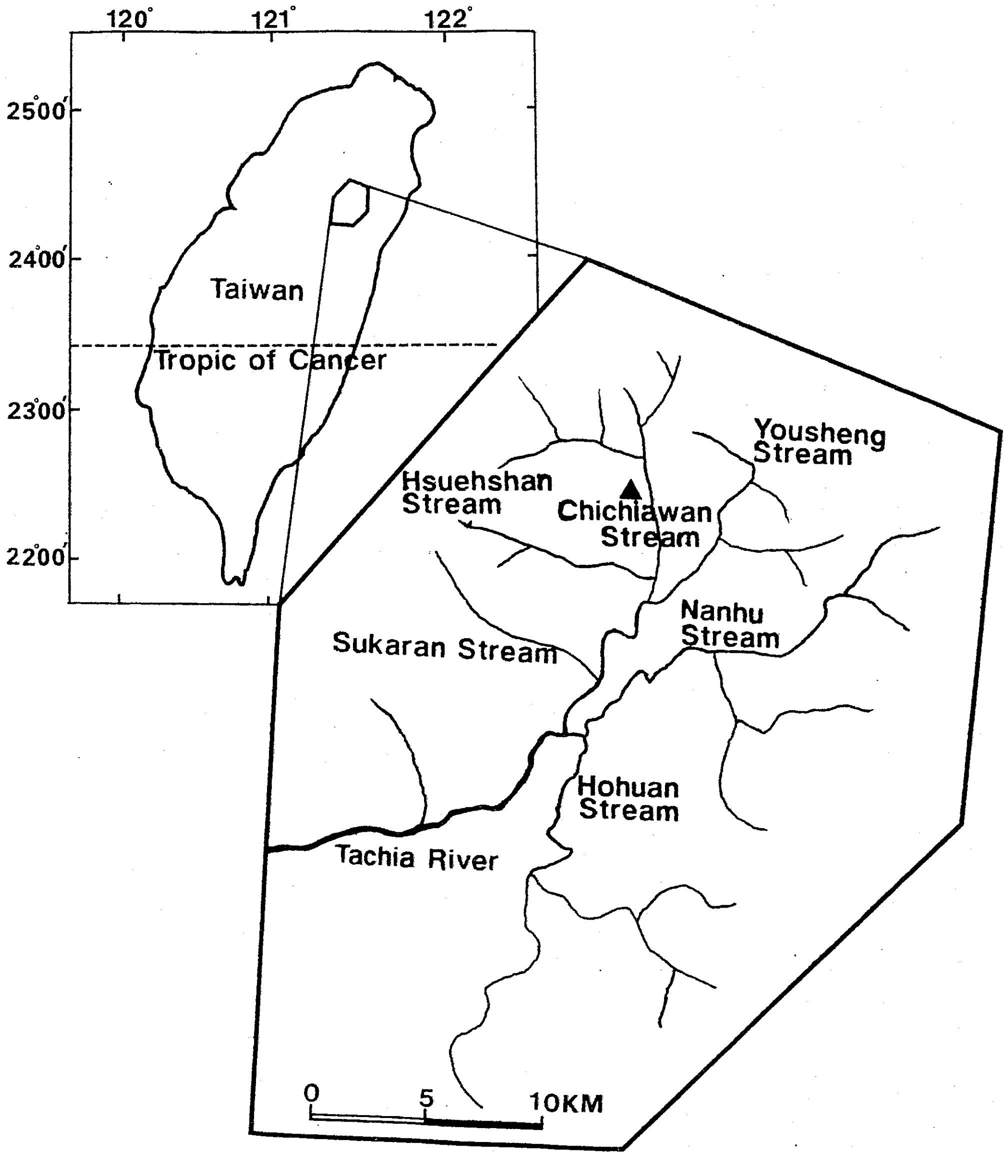


Fig. 1. Map showing tributaries of Tachia River. The filled triangle indicates the location of Wu-lin Farm headquarter. The salmon specimens used in the present study were collected from the Chichiawan Stream.

ally appeared. The ten artificially propagated specimens were collected from the salmon propagation station located on the river bank of the Chichiawan Stream near Wu-lin Farm. The Fl generation of this stock came from the Chichiawan Stream. While age composition of the specimens collected from the wild stock was not available, the specimens collected from the artificially propagated stock were known to be yearlings. After each collection, the specimen was preserved in 10% formalin and brought to laboratory for morphometric measurements and meristic countings.

With reference to Cailler et al. (1986), Hikita (1962) and Hubbs and Lagler (1967), a set of data, including a total of 34 characters, was collected from each specimen. These characters were: total length, fork length, body depth, caudal-peduncle depth, prepectoral length, prepelvic length, preanal length, length of dorsal base, length of anal base, length of dorsal fin, length of pectoral fin, length of pelvic fin, length of anal fin, head length, head depth, head width, snout length, eye diameter, upper jaw length, distance between dorsal fin and adipose fin, interorbit, dorsal soft rays, pectoral soft rays, pelvic soft rays, anal soft rays, scales in lateral line, scales above lateral line, scales below lateral line, scales between adipose fin and lateral line, scales along two rows above lateral line, branchiostegal rays, pyloric caeca, total gill rakers on the first gill arch, and vertebrae. Coverages of some of the measurements are indicated in Fig. 2. The lengths were measured twice, each to 0.05 mm with callipers, and the average was used. The meristic characters were measured 2 – 3 times and the value which appeared more than once in the countings was used.

Differences between the meristic characters counted in the present study and the published data on the Formosan salmon from Behnke et al. (1962), Jordan and Oshima (1919), Nakamura and Koshigi (1938), Teng (1959) and Watanabe and Lin (1985), were analysed using the GT2 method, an ANOVA which is based on MSD (minimum significant difference) and yields multiple comparisons among pairs of means (Sokal and Rohlf, 1981). This test was made on the assumption that all the specimens examined in these studies stemmed from fish populations of the same variance.

In addition, to study the difference between the Formosan salmon and other *Oncorhynchus* species, the results from the present study were further compared using the unpaired t-test with the published systematic account of eight species of *Oncorhynchus*, namely, *O. masou, O. keta, O. gorbuscha, O. nerka, O. kisutch, O. rhodurus, O. tshawytscha, O. kawa-*

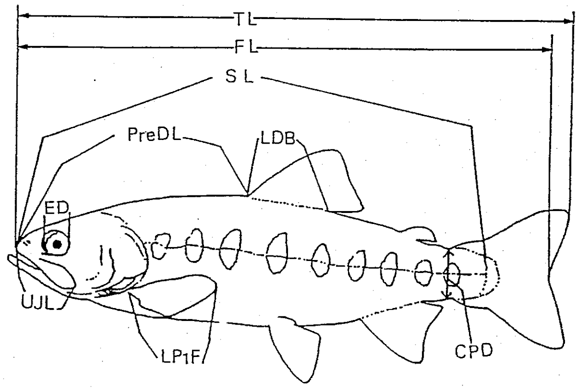


Fig. 2. Sketch diagram indicating some morphometric characters measured in the present study; where CPD, caudal-peduncle depth; ED, eye diameter; FL, fork length; LDB; length of dorsal fin base; LP1F, length of pectoral fin; PreDL, predorsal length; SL, standard length; TL, total length; UJL, upper jaw length.

murae (Hikita, 1962). Furthermore, the generic interrelationships between the Formosan salmon and the *Oncorhynchus* species were obtained using UPGMA (unweighted pair-group arithmetic average clustering) based on the average taxonomic distance. Calculation was processed using software package NTSYS-PC (Rohlf, 1988).

RESULTS AND DISCUSSIONS

Results of the measurements and the countings are presented in Tables 1-3, and are described and discussed below.

Measurements of morphometric variables

The standard lengths of specimens collected from the wild stock measured 154.58 – 296.60 mm; those from the artificial propagated stock measured 90.90 – 184.00 mm. The body weights of PW specimens were in the range between 39.00 g and 435.00 g; the PA specimens weighted between 14.00 g and 67.00 g.

The above results show a tendency that in the present study specimens collected from the wild stock are normally larger and heavier than those collected from the artificial propagation station. Measurements of other morphometric characters of the specimens also follow a similar trend (Table 1). As, in most fishes, the body length and body weight are growth parameters of an adult and hence are principally related to the age of an individual, the differences between measurements of specimens from the two stocks, namely, PW and PA, is consistent with the fact that specimens collected from the artificially propagated stock were relatively young compared with those from the wild stock.

Counts of the meristic characters and comparisons with published information on the Formosan salmon

Results of countings of fin rays, branchiostegal rays, gill rakers and vertebrae are presented in Table 2 while numbers of scales at various positions of the Formosan salmon are presented in Table 3. In these two tables, related data on the Formosan salmon from studies by Nakamura and Koshigi (1938), Behnke et al. (1962) and Watanabe and Lin (1985) are appended, along with results of GT2 tests.

Ranges of character counts of specimens (comprising both PW and PA) in the present study are: dorsal rays, 13 – 16; pectoral rays, 11 – 14; pelvic rays, 8 – 10; anal rays 11 – 15; branchiostegal rays, 9 – 14; gill rakers, 16 – 21; vertebrae, 60 – 63; scales in the lateral line, 116 – 137; scales between lateral line and the beginning of adipose fin, 15 – 24; between lateral line and of anal fin, 20 – 37; between lateral line and of dorsal fin, 23 – 37; sales in the second row above the lateral line, 120 – 150.

When these counts are compared with those published data, it shows that, between collections from different studies, a few meristic characters of the Formosan salmon are more variable than others, as indicated by results from the GT2 test (Table 2). For example, counts of dorsal rays and pectoral rays from the wild stock of the present study are significantly different from those from either Watanabe and Lin (1985) or Nakamura and Yoshigi (1938). In addition, difference in the branchiostegal rays is found between PW and PA of the present study. However,

Table 1. Ranges of measurements of various morphometric characters of the specimens collected from the Chichiawan Stream and specimens from the artificially propagated stock. N, sample size; –, data unavailable.

	Wild stock			Artificially propagated stock		
	Maximum	Minimum	N	Maximum	Minimum	N
Body weight (g)	435.00	39.00	38	67.00	14.00	9
Standard length (mm)	296.60	154.58	42	184.00	90.90	9
Total length	346.75	180.70	38	149.40	120.10	6
Fork length	335.95	174.43	39	141.40	112.90	6
Body depth	82.60	34.65	37	28.80	21.00	7
Caudal-peduncle depth	29.80	12.88	39	13.13	7.80	8
Predorsal length	157.65	76.88	41	62.00	43.30	8
Prepectoral length	87.25	38.68	40	27.80	20.30	7
Prepelvic length	182.08	88.83	40	66.70	50.00	7
Preanal length	224.23	117.30	40	87.80	65.00	7
Length of dorsal base	47.60	24.33	41	21.50	13.30	8
Length of anal base	36.40	17.18	41	13.50	10.40	7
Length of dorsal fin	48.40	27.18	41	–	–	–
Length of anal fin	40.60	21.30	20	–	–	–
Length of pectoral fin	57.20	27.10	35	23.20	15.30	8
Length of pelvic fin	43.68	23.28	35	18.60	12.10	8
Head length	94.35	41.53	41	50.38	23.90	9
Head width	44.70	13.80	40	15.00	11.00	8
Head depth	67.05	24.90	40	19.20	13.80	8
Snout length	29.98	9.65	42	12.83	5.40	10
Eye diameter	11.80	6.13	41	8.45	5.10	10
Upper jaw length	61.05	23.25	41	32.00	11.70	10
Distance between dorsal fin and adipose fin	57.13	26.25	41	24.70	17.40	8
Interorbit	25.30	10.40	42	13.20	6.30	10

Table 2. Counts of fin rays, branchiostegal rays, gill rakers and vertebrae of the Formosan salmon. For each character results of comparison of means from different studies are presented in the GT2 table. An asterisk is used to indicate that the difference larger in absolute value than the MSD value is significant at the 0.05 level. In the GT2 table data sources are shown by their abbreviations. That is, PW represents "wild stock in the present study"; PA, "artificially propagated in the present study"; W&L, from Watanabe and Lin (1985); Be, from Behnke et al. (1962); N & Y, from Nakamura and Yoshigi (1938).

(a) Number of dorsal rays

	Range	Average	SD	N	Data Source
Wild stock	13–16	14.811	0.811	37	Present study
Artificially propagated	13–16	14.000	0.925	8	Present study
Wild stock	12–15	13.903	0.473	31	Watanabe & Lin (1985)
Wild stock	12–13	13.100	0.316	10	Nakamura & Yoshigi (1938)

Results of GT2 test

$|\bar{Y}_i - \bar{Y}_j|$

		PW	PA	W&L	N&Y
MSD_{ij}	PW		0.811	0.908*	1.711*
	PA	1.089		0.097	0.900
	W&L	0.680	1.107		0.803
	N&Y	0.995	1.324	1.015	

(b) Number of pectoral rays

	Range	Average	SD	N	Data Source
Wild stock	11–14	12.073	0.787	41	Present study
Artificially propagated	12–13	12.556	0.528	9	Present study
Wild stock	12–14	13.125	0.609	32	Watanabe & Lin (1985)
Wild stock	13–14	13.200	0.447	5	Behnke et al. (1962)
Wild stock	14–15	14.100	0.316	10	Nakamura & Yoshigi (1938)

Results of GT2 test

$|\bar{Y}_i - \bar{Y}_j|$

		PW	PA	W&L	Be	N&Y
MSD_{ij}	PW		0.483	1.052*	1.127	2.027*
	PA	1.120		0.569	0.644	1.544*
	W&L	0.718	1.148		0.075	0.975
	Be	1.441	1.697	1.463		0.900
	N&Y	1.073	1.398	1.102	1.667	

Table 2. (Continued)

(c) Number of pelvic rays

	Range	Average	SD	N	Data Source
Wild stock	8–10	8.927	0.565	41	Present study
Artificially propagated	8–10	8.875	0.642	8	Present study
Wild stock	9–9	9.000	0.	5	Behnke et al. (1962)
Wild stock	9–10	9.200	0.422	10	Nakamura & Yoshigi (1938)

Results of GT2 test

$|\bar{Y}_i - \bar{Y}_j|$

		PW	PA	Be	N&Y
MSD_{ij}	PW		0.052	0.073	0.273
	PA	0.863		0.125	0.325
	Be	1.058	1.273		0.200
	N&Y	0.788	1.059	1.223	

(d) Number of anal rays

	Range	Average	SD	N	Data Source
Wild stock	11–15	13.054	0.941	37	Present study
Artificially propagated	11–14	12.125	0.834	8	Present stduy
Wild stock	11–14	12.688	0.481	32	Watanabe & Lin (1985)
Wild stock	11–13	11.600	0.782	5	Behnke et al. (1962)
Wild stock	12–13	12.700	0.483	10	Nakamura & Yoshigi (1938)

Results of GT2 test

$|\bar{Y}_i - \bar{Y}_j|$

		PW	PA	W&L	Be	N&Y
MSD_{ij}	PW		0.929	0.366	1.454	0.354
	PA	1.340		0.563	0.525	0.575
	W&L	0.830	1.358		1.088	0.012
	Be	1.637	1.959	1.653		1.100*
	N&Y	1.225	1.630	1.245	0.420	

Table 2. (Continued)

(e) Number of branchiostegal rays

	Range	Average	SD	N	Data Source
Wild stock	9–14	11.775	1.109	40	Present study
Artificially propagated	9–12	10.222	1.092	9	Present study
Wild stock	11–14	12.400	1.140	5	Behnke et al. (1962)

Results of GT2 test

		$\lvert\bar{Y}_i-\bar{Y}_j\rvert$		
		PW	PA	Be
MSD_{ij}	PW		1.553*	0.625
	PA	1.399		2.178*
	Be	1.799	2.116	

(f) Number of gill rakers

	Range	Average	SD	N	Data Source
Wild stock	16–21	18.579	0.984	38	Present study
Artificially propagated	17–20	18.286	0.953	7	Present study
Wild stock	16–20	18.312	1.048	32	Watanabe & Lin (1985)
Wild stock	17–21	19.200	1.438	5	Behnke et al. (1962)

Results of GT2 test

		$\lvert\bar{Y}_i-\bar{Y}_j\rvert$			
		PW	PA	W&L	Be
MSD_{ij}	PW		0.293	0.267	0.621
	PA	1.969		0.026	0.914
	W&L	1.032	1.795		0.888
	Be	2.046	2.519	2.068	

Table 2. (Continued)

(g) Number of vertebrae

	Range	Average	SD	N	Data Source
Wild stock	60–63	61.950	0.597	40	Present study
Artificially propagated	60–63	62.044	0.311	8	Present study
Wild stock	60–63	61.750	0.568	32	Watanabe & Lin (1985)
Wild stock	61–63	61.800	0.323	5	Behnke et al. (1962)

Results of GT2 test

$|\bar{Y}_i - \bar{Y}_j|$

		PW	PA	W&L	Be
MSD_{ij}	PW		0.094	0.200	0.150
	PA	0.932		0.294	0.244
	W&L	0.571	0.951		0.050
	Be	1.141	1.372	1.157	

among the seven characters of which pair-wise comparisons are available, the counts on pelvic rays, anal rays, gill rakers, and vertebrae are relatively consistent through these studies.

The differences in dorsal rays and pectoral rays imply that the fish were collected from population of unequal means (of these two characters). Difference in the collection site is one factor which may contribute to these differences, since geographic difference of the site may cause isolation of the fish, hence generate site specific characteristics to the fish. However, in the present comparison the extent to which the collection sites differ from each other is unclear; specimens used by Watanabe and Lin (1985) were collected from both Hsueshan Stream (a tributary of Chichiawan Stream, the collection site of the present study), Sukairan Stream and Skairan Stream, whereas the collection site was not specified in Nakamura and Yoshigi (1938). Therefore there is no sufficient evidence to support the speculation on the occurrence of the site-specific populations. Alternatively, with the wide consistency occurring in meristic characters other than dorsal rays and pectoral rays, the differences in dorsal rays and pectoral rays may thus indicate that the two characters are more variable than others through the time.

Comparisons between Formosan salmon and other members of *Oncorhynchus*

The Formosan salmon and eight other *Oncorhynchus* species, namely *O. masou, O. keta, O. gorbuscha, O. nerka, O. kisutch, O. rhodurus, O. tshawytscha* and

Table 3. Counts of scales at various parts of the Formosan salmon. Apart from results from the present study, data available from relative studies are also appended for reference.

(a) Number of scales along the lateral line

	Range	Average	N	Data Source
Wild stock	116–139	127.38	37	Present study
Artificially propagated	127–137	132.00	6	Present study
Wild stock	130–146	138.96	32	Watanabe & Lin (1985)
Wild stock	117–124	121.80	5	Behnke et al. (1962)
Wild stock	118–130	123.3	63	Teng (1959)
(Holotype)	130			Jordan & Oshima (1919)
(Paratype)	143			Jordan & Oshima (1919)

(b) Number of scales between lateral line and the beginning of the adipose fin

	Range	Average	N	Data Source
Wild stock	15–25	20.17	23	Present study
Artificially propagated	24		1	Present study
Wild stock	22–26	24.14	32	Watanabe & Lin (1985)
Wild stock	20–23	20.67	5	Behnke et al. (1962)
(SU23059)	20			Behnke et al. (1962)

(c) Number of scales between lateral line and the beginning of the anal fin

	Range	Average	N	Data Source
Wild stock	20–37	30.71	24	Present study
Artificially propagated	23		1	Present study
(Holotype)	22			Jordan & Oshima (1919)
(Paratype)	23			Jordan & Oshima (1919)

(d) Number of scales along the second row above the lateral line

	Range	Average	N	Data Soruce
Wild stock	120–149	134.86	28	Present study
Wild stock	136–150	145.08	28	Watanabe & Lin (1985)
Wild stock	130–158	139.00	5	Behnke et al. (1962)

O. kawamurae from Hikita (1962) are used in this comparison. Counts of fin rays, vertebrae, lateral line scales, gill rakes on the first gill arch, branchiostegal rays and pyloric caeca are variables available for comparison. In consideration of the variation occurring in some meristic countings between studies of the Formosan salmon, in this part of the study, except where mentioned, information on the Formosan salmon are based on specimens collected from the wild stock in the present study. Data used in the comparison are grouped and presented in Figs. 3-6. The results are described and discussed below.

Fin rays

Counts of anal rays, pectoral rays, pelvic rays of the Formosan salmon (both PW and PA) are significantly different from those of all other *Oncorhynchus* species ($p<0.05$). Moreover, the above counts of the Formosan salmon are relatively small when compared with their counterparts (Fig. 3). For example, in the eight *Oncorhynchus* species reviewed in Hikita (1962) pelvic ray counts of most *O. masou* and *O. kawamurae*, are 10, and the counts of other six species are mostly 11, whereas it is 8 in the Formosan salmon. In addition, the count of dorsal rays of the Formosan salmon is also significantly different from that of *O. keta, O. nerka, O. kisutch, O. tshawytscha* or *O. kawamurae* ($p<0.05$), even though ranges of the counts overlap widely between most species (Hikita, 1962).

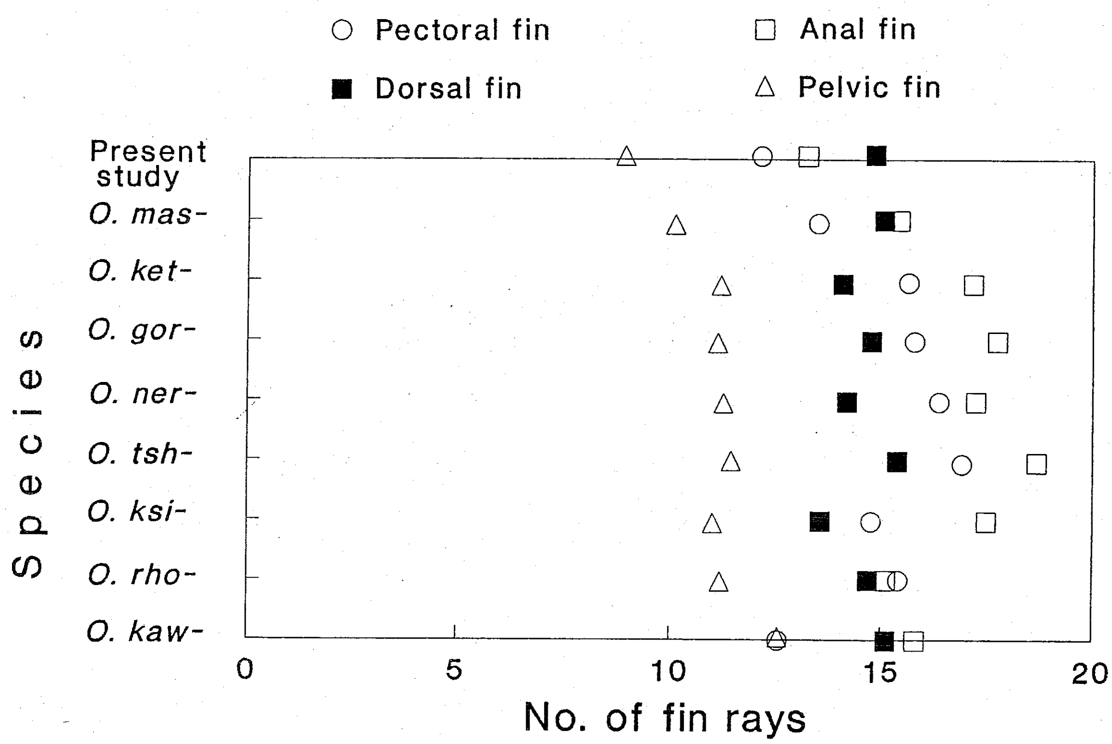


Fig. 3. The diagram showing mean numbers of fin rays of different *Oncorhynchus* species. Except the fish collected in the present study, published data from Hikita (1962) are used. *O. gor= O. gorbuscha; O. kaw= O. kawamurae; O. ket= O. keta; O. kis= O. kisutch; O. mas= O. masou; O. ner= O. nerka; O. rho= O. rhodurus; O. tsh= O. tshawytscha.*

Branchiostegal rays

With an average of 17.5, counts of branchiostegal rays of *Oncorhynchus tshawytscha* is the highest among fishes in the present comparison (Fig. 4). The number of branchiostegal rays of the Formosan salmon is significantly different from all other *Oncorhynchus* spp. ($p < 0.05$) except *O. kawamurae.*

Gill rakers

Fishes involved in this comparison can be intuitively divided into two groups according to the number of gill rakers of each fish (Fig. 4). That is, *O. gorbuscha, O. nerka* and *O. kawamurae*, which hold a higher count, may be taken in one group, whereas Formosan salmon, *O. masou, O. kisutch* and *O. tshawytscha*, which hold a lower count, be taken in another group. Nevertheless, except *O. masou* and *O. rhodurus,* the number of gill rakers of the Formosan salmon is significantly different from other *Oncorhynchus* spp. ($p<0.05$).

Vertebrae

Oncorhychus tshawytscha holds the highest count of vertebrae (in average 71.42). *Oncorhynchus keta, O. gorbuscha, O. nerka, O. kisutch, O. kawamurae, O. masou, O. rhodurus* and Formosan salmon follow after in sequence (Fig. 5). However, counts of the Formosan salmon (with an average of 61.95) are significantly different from those of all other species ($p<0.05$). The value closest to the Formosan salmon's is from *O. masou* (with an average of 64.83).

Scales in the lateral line

The highest mean number of scales in the lateral line occurs in *Oncorhynchus gorbuscha* (Fig. 5). The range of its

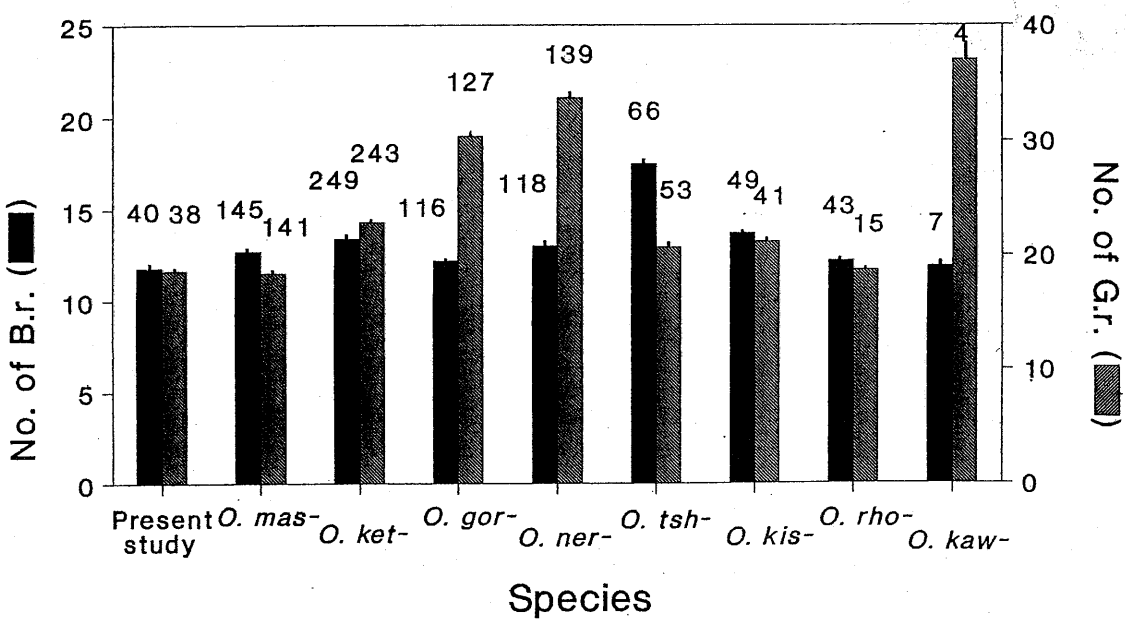


Fig. 4. The diagram showing mean branchiostegal rays (Br) and gill rakers (Gr) of different *Oncorhynchus* species. Except the fish collected in the present study, published data from Hikita (1962) are used. The vertical line above each bar indicates the value of $s_{\bar{x}}$. The sample size is shown by the numeral above each bar. Abbreviations of species names same as in Fig. 3.

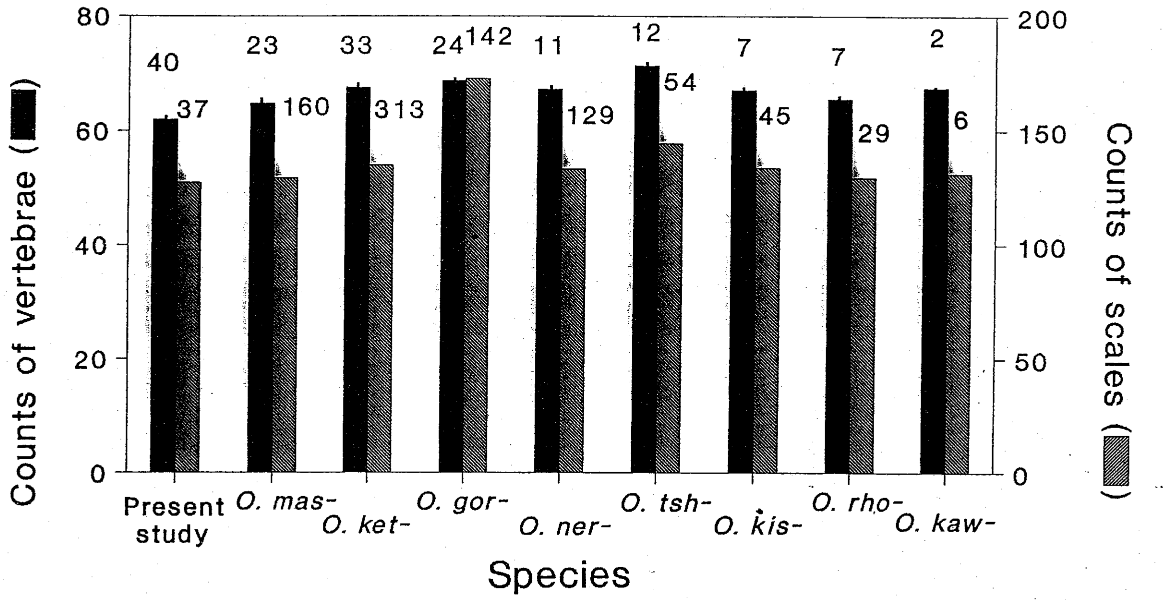


Fig. 5. The diagram showing mean lateral line scales and vertebrae of different *Oncorhynchus* species. Except the fish collected in the present study, published data from Hikita (1962) are used. The vertical line above each bar for the vertebra indicates the value of $s_{\bar{x}}$, (which is not available for scale counts). The numeral above each bar indicates the sample size. Abbreviations of species names same as in Fig. 3.

counts is 147 – 205. Except the counts of *O. tshawytscha*, which are in the range 137 – 150, counts of all other species are lower than *Oncorhynchus gorbuscha*. Ranges for Formosan salmon and *O. masou* are 116 – 139 and 115 – 138 respectively. They are the closest pair among the nine fishes involved in this comparison. However, since frequency distributions of this character are not available in Hikita (1962), further comparisons between species are not possible.

Pyloric caeca

In each of the *Oncorhynchus* species available in this comparison, numbers of the pyloric caeca seems highly variable; this is indicated by the wide range of pyloric caeca counts presented in Fig. 6. Nevertheless, Formosan salmon, *O. masou, O. kisutch, O. rhodurus* and *O. kawamurae* generally hold fewer pyloric caeca than other four species, namely *O. keta, O. gorbuscha, O. nerka* and *O. tshawytscha.* Furthermore, Formosan salmon and *O. masou* possess the lowest two means.

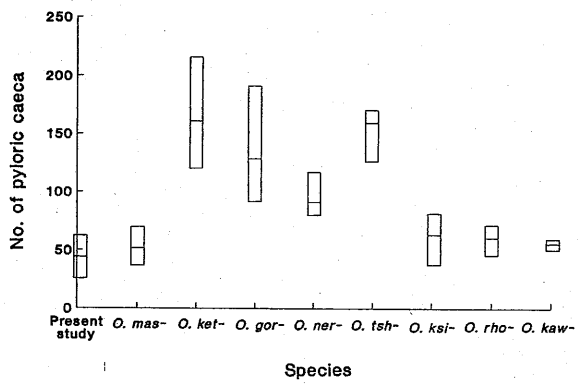


Fig. 6. Box plot showing the range of numbers of the pyloric caeca of different *Oncorhynchus* species. The mean is indicated by the horizontal line in the box. Except the fish collected in the present study, published data from Hikita (1962) are used. Abbreviations of species names same as in Fig. 3.

Table 4. Twenty five variables used in the UPGMA. Data under "Present study" are the averages of PW and PA; data for other salmonids are based on Hikita (1962). For explanation of species names see text.

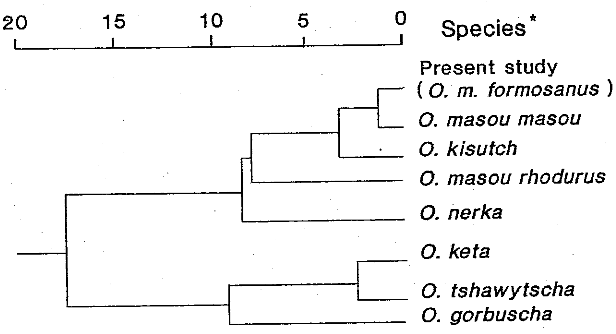
Variables*	Present study	*O. m. masou*	*O. keta*	*O. gorbuscha*	*O. nerk*	*O. tshawytscha*	*O. kisutch*	*O. m. rhodurus*
SL/BD	4.220	4.050	4.700	4.050	3.650	3.800	3.650	4.600
HL/CPD	2.974	2.800	3.360	3.680	2.865	3.110	3.065	2.805
SL/PreDL	2.063	2.100	2.050	2.050	2.250	2.200	2.100	2.150
SL/PreP1L	4.050	4.650	4.550	4.500	5.100	4.550	4.400	4.800
SL/PreP2L	1.749	1.500	1.800	1.800	1.950	1.850	1.650	1.700
SL/PreAL	1.323	1.350	1.395	1.445	1.395	1.425	1.600	1.600
HL/LDFB	1.621	1.850	2.000	2.150	2.100	2.400	2.200	1.850
HL/LAFB	2.009	2.050	2.400	2.650	2.450	3.450	2.650	2.100
HL/LP1FB	1.531	1.695	2.150	1.750	1.550	1.750	1.850	1.650
HL/LP2FB	1.900	2.050	3.300	2.300	2.200	2.200	2.300	2.200
SL/HL	3.664	4.050	4.250	4.400	4.250	4.050	3.700	4.150
HL/SNL	4.063	3.250	3.000	2.950	3.300	2.850	3.100	3.250
HL/ED	6.238	7.450	4.250	9.325	7.050	10.500	8.500	5.950
HL/Interorbit	3.675	3.300	2.150	2.800	2.800	2.800	2.550	3.300
Dorsal fin rays	14.406	15.086	13.969	14.652	14.000	15.294	13.440	14.658
Anal fin rays	12.590	15.391	17.062	17.603	17.152	18.562	17.320	15.000
Pectoral fin rays	12.315	14.333	15.545	15.678	16.195	16.791	14.710	15.282
Pelvic fin rays	8.901	10.011	11.065	11.041	11.143	11.417	10.885	11.103
Scales along 1.1.	129.690	129.400	135.060	172.840	133.410	144.610	133.860	169.680
Branchiostegal rays	10.999	12.683	13.442	12.172	12.975	17.500	13.735	12.209
Pyloric caeca	45.930	47.050	160.610	126.190	91.000	159.610	62.600	58.000
Gill raker	18.433	18.404	22.918	30.425	33.669	20.679	21.220	18.667
Vertebrae	61.997	64.826	67.576	68.750	67.273	71.417	67.143	65.571
Caudal vertebrae	25.811	27.200	27.727	27.792	26.500	30.333	27.429	28.000
Precaudal vertebrae	36.155	38.556	39.879	40.958	40.250	41.111	40.714	37.750

* The following characters are presented in abbreviations (as in parentheses).
Standard length (SL); Body depth (BD); Head length (HL); Caudal-peduncle depth (CPD); Predorsal length (PreDL); Prepectoral length (PreP1L); Prepelvic length (PreP2L); Preanal length (PreAL); Length of dorsal fin base (LDFB); Length of anal fin base (LAFB); Length of prectoral fin base (LP1FB); Length of pelvic fin base (LP2FB); Snout length (SNL); Eye diameter (ED).

Generic interrelationship

Twenty five meristic and transformed morphometric characters of the *Oncorhynchus* species (Table 4) are used to calculate the pair-wise average taxonomic distance, which was then used to construct a dendrogram by UPGMA to show the generic interrelationship among these fishes. In this treatment *Oncorhynchus kawamurae* was not included because the data set on this salmonid in Hikita (1962) had some missing values. Furthermore, species names used by Hikita (1962) are modified after Masuda et al. (1984), who suggest that in the genus *Oncorhynchus* there are six species, namely, *O. masou, O. gorbuscha, O. keta, O. kisutch, O. tshawytscha* and *O. nerka.* That is, *O. rhodurus and O. masou,* two species included in the review of Hikita (1962), are considered as two subspecies, namely, *O. masou rhodurus* and *O. masou masou* respectively, (despite the currently existing confusions on the taxonomic status of *O. rhodurus* (Kawanabe, 1989; Kimura, 1989)). In addition, *O. masou formosanus,* the scientific name suggested for the Formosan salmon (Watanabe and Lin, 1985), is tentatively adopted for the fish used in the present study.

The reulst of the UPGMA (Fig. 7) shows that Formosan salmon and other *Oncorhynchus* species can be divided into two main groups; one includes Formosan salmon (*O. m. formosanus*), *O. m. masou, O. kisutch, O. m. rhodurus* and *O. nerka*; the other includes *O. keta, O. tshawytscha* and *O. gorbuscha.* It also shows that *O. m. formosanus* is more closely related to *O. m. masou* than to any other *Oncorhynchus* species. This is consistent with the finding obtained from comparisons described in the above section, that in most



* Species names based on Masuda (1984)

Fig. 7. Dendrogram constructed by UPGMA based on average taxonomic distance, showing the interrelationship between *Oncorhynchus* species.

meristic characters both *O. m. formosanus* and *O. m. masou* commonly hold the lowest values. It is interesting to note that the low meristic values occur in *O. m. formosanus* is also consistent with the general pattern that fishes living in a higher longitude might hold a higher meristic values than fishes otherwise (Barlow, 1961), as that particularly found in meristic characters such as vertebrae (Barlow, 1961; Tanning, 1952).

The dendrogram shows that the three subspecies of *O. masou* can be taken into one group. However, as indicated in Fig. 7, this group would also include *O. kisutch.* Moreover, *O. kisutch* has closer interrelationship than *O. m. rhodurus* to the lower level sub-group which is composed of *O. m. formosanus* and *O. m. masou.* Therefore, it is suggested that further information is needed to account for the coverage of such a distinct species as *O. kisutch* in the *O. masou* group (Fig. 7). Furthermore, the information provided by the dendrogram is still insufficient to show how closely the *O. m. formosanus* is related to *O. m. rhodurus* and

O. m. masou. Putting these things together, it seems that, like some other salmonids (Kawanabe, 1989; Kimura, 1989), the problems on the systematic position of the Formosan salmon remains. To list the least, whether the present *O. m. formosanus* and *O. m. masou* are two distinct subspecies or are merely two populations of one subspecies could be a typical question of this kind.

The present study used the morphometric and meristic variables as a parameter to look at the systematic position of the Formosan salmon (c.f. Thomas et al., 1986). Unfortunately the results lack the power for the clarification of the systematic status of this landlocked salmon. Thus it is anticipated further studies on behaviour, ecology and/or genetics may help the elucidation of the ambiguity of the status of Formosan salmon.

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臺灣陸封型櫻鮭形質測定及與其他 *Oncorhynchus* 屬魚種間之比較研究

詹榮桂　莊鈴川　林曜松　張崑雄

現存於大甲溪上游七家灣溪一帶的臺灣陸封性鮭魚（亦卽櫻花鉤吻鮭，或稱臺灣鱒、梨山鱒或石川氏鮭魚；泰雅族語則稱之爲本邦（Bunban））由於屬於冰河時期的遺物，因此其種原以及其在鮭魚科櫻鱒屬 *Oncorhynchus* 中的地位，一直頗受重視。西元 1919 年，Jordan 和 Oshima（大島正滿）根據兩尾標本的形質將櫻花鉤吻鮭命名爲 *Salmo formosanus* Jordan and Oshima。1934 年，大島正滿根據其他標本的鱗片構造及活魚體側有紅色斑點等特徵，將學名改爲 *Oncorhynchus formosanus*。1935 年，大島正滿到大甲溪上游採集鑑定標本後，認定其與日本北方所產的櫻鱒相同，學名因此再度更改，成爲 *Oncorhynchus masou* (Brevoort)。Behnke 等在 1962 年就櫻花鉤吻鮭的分類問題加以探討，認爲這些櫻花鉤吻鮭的分類可能有三種情況；它可能是全部屬於同一個種，這時應將它視爲櫻鱒 *O. masou* 的一個亞種。不過，這些櫻花鉤吻鮭也有可能是含有二或三個種。Watanabe 和 Lin 在 1985 年亦認爲櫻花鉤吻鮭應該是櫻鱒的亞種，並將學名定爲 *Oncorhynchus masou formosanus*。

本研究以於民國 75 年 10 月至 76 年 12 月間在七家灣溪畔所撿拾的 42 尾以及人工繁殖養成的 10 尾櫻花鉤吻鮭爲材料，做計量以及計數形質的測定，並將結果與以前學者們所發表的有關櫻花鉤吻鮭的資料加以比較。此外，並拿櫻花鉤吻鮭與櫻鱒 *Oncorhynchus* 屬的其它魚種相比較，進而推研其與這些魚種之間的類緣關係。

報告中除了報導目前櫻花鉤吻鮭形質測定上的詳細資料外，有關比較結果並顯示：除了背鰭軟條數外，在許多其他計量形質上，本研究所得與前人的結果之間並無顯著差異。種間的比較則顯示：櫻花鉤吻鮭與櫻鱒亞種 *Oncorhynchus masou masou* 之間，在許多計量形質上，要比其他魚種之間接近。另外以 Average taxonomic distance 爲依據，以 UPGMA 法處理後所得的樹狀種緣關係圖亦顯示櫻花鉤吻鮭與櫻鱒亞種之間的類緣關係爲最密切。

這些結果支持「櫻花鉤吻鮭與櫻鱒亞種二者之間類緣相近」的說法，不過因爲這二者之間的關係比櫻鱒亞種 *Oncorhynchus masou* 與其他亞種之間的關係還要密切，因此就分類地位而言，櫻花鉤吻鮭的學名倒底是否應爲 *Oncorhynchus masou formosanus*，亦即與日本所產的櫻鱒（亦即上述的櫻鱒亞種）一樣，皆爲 *Oncorhynchus masou* 種下的一個亞種，還是櫻花鉤吻鮭與日本所產的櫻鱒只是經地理隔絕而形成的兩個族羣，則猶待進一步的探討。